

## THE EXCRETORY SYSTEM IN DIGENEA. II.

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### OBSERVATIONS ON THE EXCRETORY SYSTEM IN DISTOME CERCARÆ.<sup>1</sup>

The diverse groups connoted by the term "distome cercariae" are found to be decidedly heterogeneous when the reproductive and excretory systems are examined. Even the nervous system is extraordinarily modified in one family of this group, the Schistosomatidæ. Students of distome cercariae have commonly made mention of the bladder and have frequently observed the main collecting tubules of the excretory system. Only infrequently, however, have they traced out accurately the auxiliary tubules and made an exact analysis of the flame cells at the distal ends of the capillaries. Even as accurate an observer as Looss has often been unable to analyze the system in material which was available for study as living mounts. Failure to determine the number of flame cells and their exact relationship to the collecting tubules may be due to (1) paucity of material at hand, (2) concealment of the cells by cystogenous or mucin glands or heavy and spinose integument, or (3) insufficient time to make careful observations at the exact moment when the material is best fitted for study. In general, mature free-swimming cercariae are much the best for this study and freshly dissected material is much better to work on than that which has been standing for several hours. It is true, however, that material may present seemingly insuperable difficulties for the study of the excretory system at a certain time or when taken from a certain place, while at another time or in another locality the study of the same species may be one of comparative ease.

Cort has frequently noted that the study of the excretory system is both tedious and wearisome. The writer may add that a successful analysis of the system requires greater care and more poise of judgment than that of any other system of the fluke.

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It is the purpose of this paper to present data on the excretory system of three distinct groups of distome cercariæ, the echinostome cercariæ, the xiphidiocercariæ and the furco-cercariæ, and to show how these data may be used to supplement the anatomical relationships based on other fundamental systems of these platodes.

#### ECHINOSTOME CERCARIÆ.

These cercariæ, frequently designated as the offspring of rediæ, with a collar of spines at the anterior end of the body, may be as readily recognized by the pair of heavy collecting tubules extending from the bladder to the region of the pharynx, where they become constricted and reflex on themselves in triangular fashion (see Figs. 1 and 2). The manner in which the flame cells are disposed, together with their number, and the course of the tubule in the tail offer a method for separating larval echinostomes into two quite distinct groups.

The more simple of these groups, as illustrated in Fig. 1, shows the collecting tubule ending in the triangular flexure and only three flame cells for each half of the body. The cells are situated at the ends of small capillaries which empty, the one at the end, the others at the sides of the triangle. No other flame cells occur along the entire course of the tubules. In the tail a single median tubule runs from the distal end forward into the bladder. Of the cercariæ in which the flame-cell count has been satisfactorily worked out, two species fall into this group, *Cercaria chisolenata* Faust, 1918, and *C. trisolenata* Faust, 1917.

The second or more complex type is one in which the constricted tubule does not end in the region of the triangular flexure lateral to the pharynx but continues caudad to the posterior region of the body. Commonly (Fig. 2), when this secondary portion of the tubule reaches the posterior region of the body, it bends forward and continues to the region of the pharynx. Numerous flame cells, constant for each species, are connected by minute capillaries with this tertiary portion of the tubule. In *Cercaria acanthostoma* Faust, 1918, sixteen flame cells occur along each tubule. In *Cercaria complexa* nov. spec. the number is fifteen. In this type also the main collecting tubule of the tail, after coursing distad for a short distance, bifurcates and opens on each side through a simple pore. To this type belong *C. trivolvæ* Cort

and *C. reflexae* Cort in which the flame cells have not been worked out. The cercaria of *Echinostomum revolutum* (Froel.) is also a

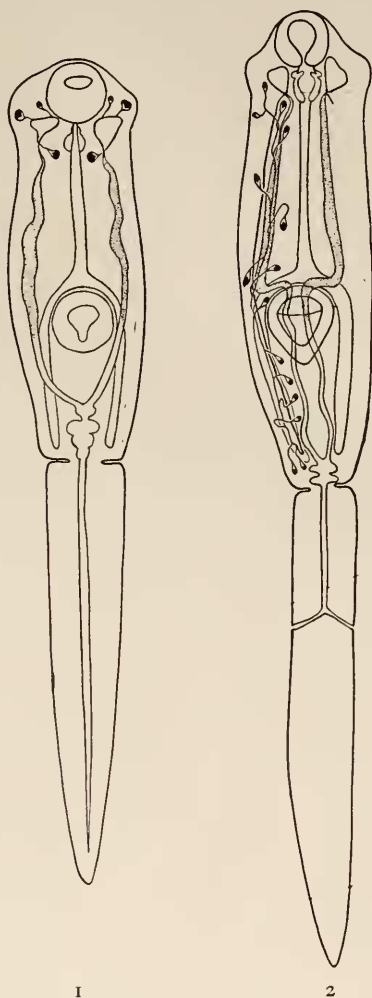


FIG. 1. *Cercaria chisolenata* Faust, ventral view, showing excretory and digestive systems.  $\times 105$ .

FIG. 2. *Cercaria complexa* nov. spec., ventral view, showing excretory and digestive systems.  $\times 170$ .

member of this group but is not entirely typical, for in this species the tertiary portion of the collecting tubule arises as a bifurcating branch from the mid-region of the secondary portion of the canal. Flame cells occur along both rami of the tertiary

tubule and probably also along the posterior part of the secondary tubule. The exact number of flame cells for each side of the body is not clearly shown but somewhere between eighteen and twenty may be counted (Looss, 1894: Fig. 191).

A species showing relationships intermediate between these two groups is *Cercaria biflexa* Faust, 1917. Both secondary and tertiary portions of the tubule occur here (Faust, 1918, Fig. 138), but they are confined entirely to the head region of the body. Numbers of tributaries to the primary tubule (Faust, 1918, Fig. 135) empty into that canal but no flame cells have been found in connection with them. In the tail of this species the main collecting tubule forks about two-fifths the way distad. The forks continue to the end of the tail but have not been found to end in pores to the exterior. Numerous branches empty into the single and bifurcated portions of the canal.

In the matter of origin the species with three flame cells in the anterior end of the worm are undoubtedly the simpler. It is not improbable that the three anteriormost flame cells of the more complex type are homologous to the three cells of the simpler type. This theory is supported by the evidence from *C. biflexa*, which, with the flexures similar to *C. complexa*, has the flame cells of the anteriormost portion of the tertiary tubule.

In view of the relationship existing among these species it seems feasible to classify them in groups on the basis of a *flame-cell formula*. Thus the flame-cell formula of *Cercaria chisolenata*, *C. trisolenata* and *C. biflexa* is 3, that of *C. complexa* is  $15 = (3 + 12)$ , and that of *C. acanthostoma* is  $16 = (3 + 13)$ . Further study of the flame cells in larval echinostomes will probably furnish evidence of other types and many other points of fundamental interest.

#### XIPHIDIOCERCARIÆ.

Anatomically the xiphidiocercariæ have little in common. Each species quite probably has a distinct type of stylet but no satisfactory classification is likely to result on the basis of this larval piercing organ. Likewise the genital and excretory systems show very great differentiation. The writer (1918, 38-40) has shown and described some of the fundamental types of bladder and main collecting tubules of this group. Ordinarily

the collecting tubules arrange themselves in anterior and posterior branches.

The first xiphidiocercaria in which the writer was able to make an analysis of the number and relation of flame cells was *Cercaria isocotylea* Cort (Faust, 1918a; also Fig. 3, this paper).

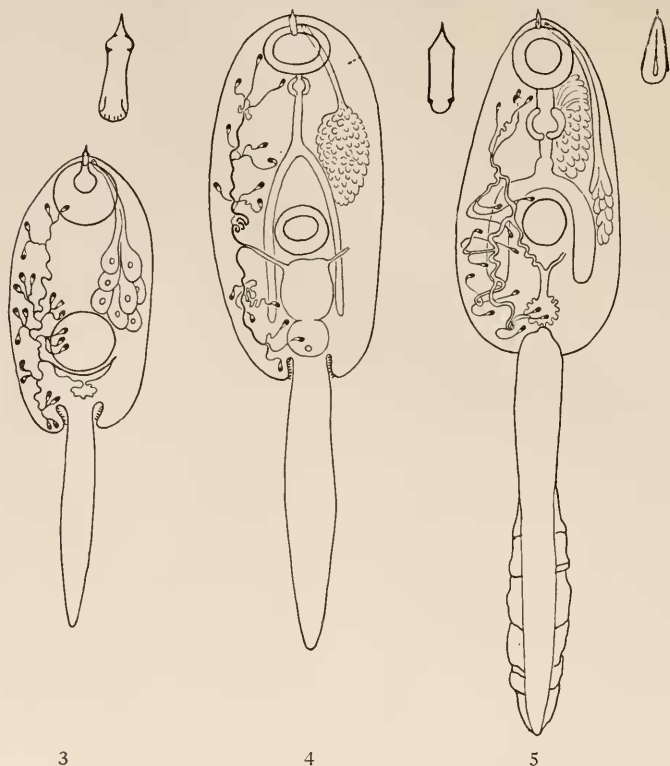


FIG. 3. *Cercaria isocotylea* Cort, ventral view, showing excretory system and mucin glands.  $\times 170$ . 3a, stylet,  $\times 540$ .

FIG. 4. *Cercaria candelabra* nov. spec., ventral view, showing excretory and digestive systems.  $\times 170$ . 4a, stylet,  $\times 540$ .

FIG. 5. *Cercaria trifurcata* nov. spec., ventral view, showing excretory and digestive systems.  $\times 105$ . 5a, stylet,  $\times 540$ .

The number of flame cells is large for a cercaria and the arrangement is complex. Placing the cells of this species into anterior and posterior groups respectively, the flame-cell formula is

$$22 = ([2 + 2 + 3 + 3 + 3 + 3] + [2 + 2 + 2]).$$

More recently the writer has studied the excretory system in two xiphidiocercariae, also from Urbana, Illinois, *C. trifurcata*

nov. spec., and *C. candelabra* nov. spec., both with an equal number of flame cells and with the same number to the group, but with a different disposition of the groups anterior and posterior. Thus the flame-cell formula of *C. trifurcata* is  $15 = ([3 + 3] + [3 + 3 + 3])$ , while that of *C. candelabra* is  $15 = ([3 + 3 + 3] + [3 + 3])$ .

Although these three species constitute the only known xiphidio-cercariae in which the flame-cell number and grouping have been worked out to a certainty, very considerable light is thrown on the subject by a comparison of these larval species with related adult species. *Allocreadium isoporum* (Looss, 1894, Fig. 103) has a flame-cell formula of  $24 = ([4 + 4 + 4 + 4] + [4 + 4])$ . The larva is a stylet cercaria with an unusually large tail. The larva of *Acrolichanus petalosa*, belonging to the same family, has the same fundamental flame-cell grouping but reversed as regards number of units disposed anterior and posterior. The formula is  $12 = ([2 + 2] + [2 + 2 + 2 + 2])$ . *Anchitrema sanguineum* (Looss, 1896, Fig. 77) has a flame-cell formula of the same number of groups but different disposition of the groups and different numbers of cells within the groups, i. e.,  $16 = ([2 + 3 + 3] + [3 + 3 + 2])$ .

Two plagiorchine species, *Haplometra cylindracea* and *Opisthoglyphe endolobum* (Looss, 1894, Figs. 29, 163) have larvae which are typically xiphidiocercariae. Both of these adult species have the same flame-cell formula,  $18 = ([3 + 3 + 3] + [3 + 3 + 3])$ . The very young distomulum of *Opisthoglyphe* has a formula of  $6 = ([1 + 1 + 1] + [1 + 1 + 1])$ , from which it is plainly to be seen that the adult condition is derived by a triad splitting of each fundamental group. That species in two different subfamilies of the Plagiorchidae should have identical flame-cell formulae is quite significant.

Again, certain subfamilies of the Brachycoeliidae, in which the larvae are thought to be xiphidiocercariae, have a flame-cell formula of  $12 = ([3 + 3] + [3 + 3])$ , while *Microphallus opacus* (Wright, 1912), belonging to another subfamily of the Brachycoeliidae, has a formula of  $8 = ([2 + 2] + [2 + 2])$ . Analysis shows that these two species have a common larval denominator, namely  $4 = ([1 + 1] + [1 + 1])$ . In other words, the mathematical exactness of flame-cell formation in this family makes it

possible to calculate the flame-cell formula of the cercaria from the condition of the adult.

The study of the flame-cell structure in the xiphidiocercariæ and comparison of the system with that of the related adult flukes show in the first place that the fundamental basis of the system is the number and disposition of the flame-cell groups. Knowledge of the structure of the excretory system in the Plagiorchiidæ and Brachycœliidæ makes it possible to state that this fundament in these groups is a family or subfamily character. The number of flame cells in each basic group is of lesser importance. Thus in the plagiorchiine species, where the species is known, triad groups are the rule, but in the brachycœliine species diad formation occurs in one subfamily and triad formation in another. In the second place this study has caused the writer to believe that this system is decidedly conservative in the xiphidiocercariæ.

A study of *Cercaria trifurcata* and *C. candelabra* shows these species to have a flame-cell formula intermediate in form between that of the Brachycœliidæ and the Plagiorchiidæ. *C. trifurcata* represents a type in which the anterior fundament is brachycœliine and the posterior fundament plagiorchiine, while *C. candelabra* represents just the reversed condition. On account of the large number of flame cells already present in the larva it is highly probable that both of these species represent a condition of flame-cell development which for the cercariæ is somewhat more precocious than that of the larvæ of the Brachycœliidæ and the Plagiorchiidæ. The system in *C. isocotylea* has reached a high degree of complexity which bears homologous relationships to no other known system in larval or adult flukes.

#### FURCOCERCARIÆ.

The forked-tailed cercariæ have secured more than ordinary attention during the past few years because experimental evidence has shown some of them to have a genetic relationship to the three human blood flukes, *Schistosoma hæmatobium*, *S. mansoni* and *S. japonicum*. Cort (1918) has made a careful analysis of the excretory systems in five furcocercariæ and the writer (1918a) has previously published flame-cell data for the species *C. gigas*. The writer's study of four additional species tends both to con-



firm Cort's data and, in supplementing and expanding these data, to emphasize the writer's previous view (1918a, 108) that it seems "reasonable to recognize a complete series of larva forms from those with a pharynx sphincter . . . to the human schistosome cercariæ."

Of the ten species of forked-tailed cercariæ for which adequate data are at hand with respect to the flame-cell structure, the cercaria of *Schistosoma japonicum* presents the most simple basic plan. Following the method previously used in this paper, the flame-cell formula of this species is  $4 = (2 + 2)$ . That one

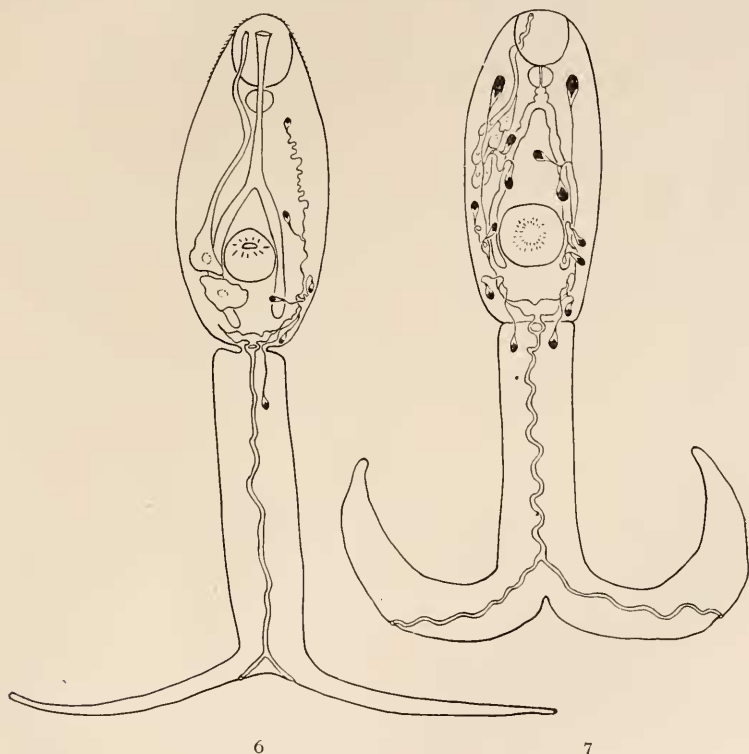


FIG. 6. *Cercaria furcicauda* nov. spec., ventral view, showing excretory and digestive systems.  $\times 170$ .

FIG. 7. *Cercaria robusticauda* nov. spec., ventral view, showing excretory and digestive systems.  $\times 540$ .

of these flame cells in each lateral circuit is found in the caudal portion of the larva is incidental rather than fundamental. The species *Cercaria douthitti* and *C. elephantis* of Cort represent



a type with a slightly more complex formula,  $6 = (3 + 3)$ . The fundament is, however, just the same,  $2 = (1 + 1)$ , so that these two may be considered two subdivisions of one larger group, all members of which have the same basic formula.

A simple condition of a stage in advance of this primitive group cited above is expressed in the excretory system of *Cercaria furcicauda* nov. spec. (Fig. 6), in which there are three

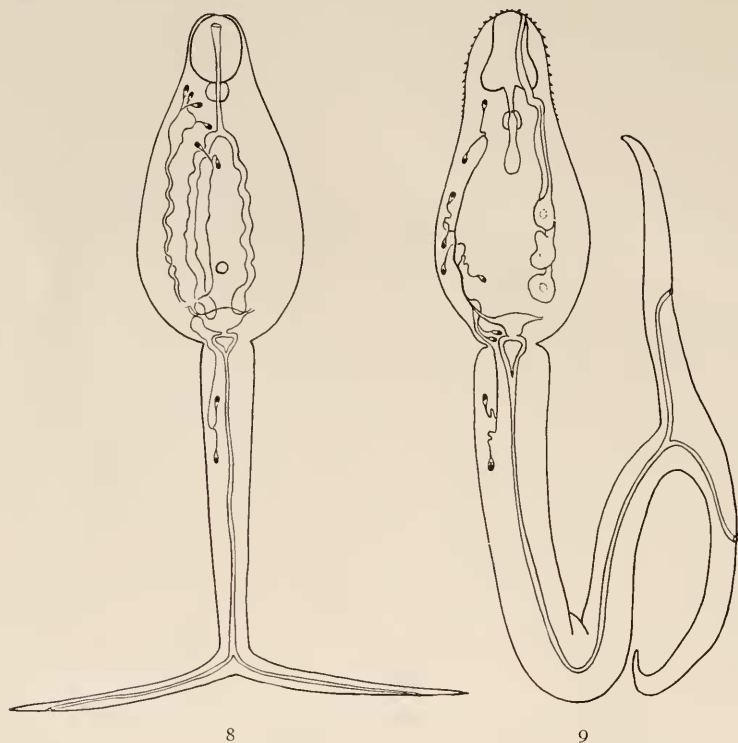


FIG. 8. *Cercaria quattuor-solenata* nov. spec., ventral view, showing excretory and digestive systems.  $\times 105$ .

FIG. 9. *Cercaria rhabdocaeca* nov. spec., ventral view, showing excretory and digestive systems.  $\times 330$ .

instead of two basic groups. The formula for the flame cells in this species is  $6 = (2 + 2 + 2)$ . One of these flame cells is in the tail. Two species, evidently differing in minor characters but bound together by the same number and arrangement of flame cells are *C. emarginata* and *C. douglasi*. These differ from

*C. furcicauda* in having three flame cells instead of two in the first (anterior) group. The formula for these species is  $7 = (3 + 2 + 2)$ . In *Cercaria robusticauda* (Fig. 7) there are the same number of flame cells as in *C. emarginata* and *C. douglasi*, but the size of the anteriormost is evident proof of its double nature. Hence the formula for this species is  $7 = (1 + 2 + 2 + 2)$ . One of these cells runs into the tail. This species is transitional between the larvæ with seven flame cells in three groups and *C. quattuor-solenata* nov. spec.

*C. quattuor-solenata* (Fig. 8) represents a condition in which a full additional flame-cell unit has been provided. Its formula is  $8 = (2 + 2 + 2 + 2)$ . Incidentally, the main collecting tubule in this species has been shortened to a minimum, while the four secondary tubules have been lengthened accordingly.

In *Cercaria rhabdocæca* nov. spec. (Fig. 9) five fundamental flame-cell groups are found, so that the formula is  $10 = (2 + 2 + 2 + 2 + 2)$ .

The flame-cell arrangement in *Cercaria gigas* (Fig. 10) is apparently unrelated to any of the foregoing species. Ten flame cells have been found on each side of the body of the cercaria and one in the tail. By inspection the formula would seem to be  $10 = (2 + 1 + 1 + 1 + 1 + 3 + 1)$ . That this may constitute a seven-fold grouping, in which two of the groups have divided, is supported in part by the fact that the single cells are somewhat larger than the cells of the units where the division has taken place, but the evidence is not entirely convincing. In the mature cercaria of this species the flame cell in the tail has no direct connection with the cells or tubules of the body proper. Its outlet is through a simple longitudinal



FIG. 10. *Cercaria gigas* Faust, dorsal view, showing excretory system on right side of body.  $\times 540$ .

vessel which empties into the bladder at the side of the median collecting tubule of the tail, just behind *the island of Cort*.

In all of these furcocercariæ, as well as in others where the flame cells have not been worked out, there is a forking of the caudal excretory tubule at the junction of furci with tail trunk. The forked tubules empty through simple pores at the sides or distal extremity of the tail-furci. Comparison of the point of opening of these pores in various species shows that in the cercaria of *Schistosoma japonicum*, *C. douthitti* and *C. elephantis* the openings are at the tips of the furci; that in most other forms they are half-way out on the sides; but that in *C. furcicauda* the outlets are near the origin of the furci (Fig. 6). Thus the writer sees no consistent correlation between the flame-cell formulæ and the point of outlet of the caudal tubules.

In furcocercariæ the excretory system is apparently always provided with *the island of Cort*.

Analysis of the flame-cell fundamentals in this group shows a simple basic plan and an unusually complete series of stages from the simplest combination of units (cercaria of *S. japonicum*)

TABLE I.

METHODS FOR DISTINGUISHING THE BETTER KNOWN FORKED-TAILED CERCARIÆ.

Species.	Flame-cell Formula.	Digestive Tract.	Eye-spots.
Cercaria of <i>Schistosoma japonicum</i> .....	4 = (2+2)	pharynx absent, 5 pairs mucin glands.	absent.
<i>Cercaria douthitti</i> .....	6 = (3+3)	pharynx absent, 5 pairs mucin glands.	present.
<i>Cercaria elephantis</i> .....	6 = (3+3)	pharynx absent, 25-30 pairs mucin glands.	present.
<i>Cercaria furcicauda</i> ....	6 = (2+2+2)	pharynx present, 2 pairs mucin glands.	absent.
<i>Cercaria emarginata</i> ....	7 = (3+2+2)	pharynx present, mucin glands?	absent.
<i>Cercaria douglasi</i> .....	7 = (3+2+2)	pharynx present, 2 pairs mucin glands.	absent.
<i>Cercaria robusticauda</i> ...	7 = (1+2+2+2)	pharynx glandular, 6 pairs mucin glands.	absent.
<i>Cercaria quattuor-solenata</i> .....	8 = (2+2+2+2)	pharynx present, no mucin glands.	absent.
<i>Cercaria rhabdocæca</i> ....	10 = (2+2+2+2+2)	pharynx present, rhabdocæ gut, 3 pairs mucin glands.	absent.
<i>Cercaria gigas</i> .....	10 = (2+1+1+1+1+3+1) (?)	pharynx absent, mucin glands many, of two kinds.	present.

to a rather large aggregate of such units (*C. rhabdocæca*). *C. gigas* is apparently not related to this series, since an analysis of its flame cells fails to show any direct correlation with the established series.

#### DISCUSSION.

The data presented in this paper are of fundamental significance in establishing the relationships of various larval flukes to one another and of larvæ to adults. Present knowledge not only preponderates in favor of the view that the number of flame cells in the species is constant, but establishes the belief also that the same basic number and arrangement of flame cells exist within families or subfamilies. When once the number and disposition of flame cells has been established for a particular group it will be possible to predict the flame-cell formula of the larvæ. Thus a larva to belong to the Schistosomatidæ *sensu stricto* should possess a flame-cell arrangement consistent with the *common denominator* which the apharyngeal species of furcocercariæ possess in common, namely  $2 = (1 + 1)$ ; and a plagiorchiine species should have the common formula of that family,  $6 = ([1 + 1 + 1] + [1 + 1 + 1])$ ; and brachycœliine species should follow the scheme  $4 = ([1 + 1] + [1 + 1])$ . This accords with Cort's thesis on the conservatism of the excretory system, but it suggests, from the number of types already known, a larger number of possibilities of flame-cell arrangement than had been previously anticipated, and, accordingly, a larger number of family groups than the present knowledge of adult flukes postulates.

Because the number of basic groups is the most significant point in the analysis of the flame-cell arrangement of cercariæ and adults alike, there is justification for presenting general formulæ of flame-cell units which will apply equally well to all species of the same group. These formulæ are readily obtained if the *common denominator* of the species of the same group is taken and literal equivalents substituted for the numbers involved. Thus for the species of Schistosomatidæ the formula would read  $\alpha + \beta$ ; for Brachycœliidæ  $\alpha' + \beta' + \alpha'' + \beta''$ , where the primed letters represent the anterior groups and the double-primed letters represent the posterior groups. Under

this scheme the echinostome larvæ with three flame cells on a side are given the formula of  $\alpha$ , while those with other flame cells distributed along the tertiary collecting tubule behind the  $\alpha$  group would be designated as  $\alpha + \beta^n$ . The full scheme for litteral formulæ for the larval and adult flukes where the flame cells have been best analyzed is presented in the following table (Table II.).

TABLE II.

## GENERAL FORMULÆ FOR FLAME-CELL ARRANGEMENT IN DISTOMATA.

## ECHINOSTOMES.

<i>Cercaria chisolenata</i>	}	..... $\alpha$
<i>Cercaria trisolenata</i>		
<i>Cercaria biflexa</i>		
<i>Cercaria complexa</i>	}	..... $\alpha + \beta^n$
<i>Cercaria acanthostoma</i>		

## XIPHIDIOCERCARIÆ.

<i>Cercaria bifurcata</i> .....	$\alpha' + \beta' + \alpha'' + \beta'' + \gamma''$
<i>Cercaria candelabra</i> .....	$\alpha' + \beta' + \gamma' + \alpha'' + \beta''$
<i>Cercaria isocotylea</i> .....	$\alpha' + \beta' + \gamma' + \vartheta' + \epsilon' + \xi' + \alpha'' + \beta'' + \gamma''$

BRACHYCELIDÆ.....  $\alpha' + \beta' + \alpha'' + \beta''$ PLAGIORCHIIDÆ.....  $\alpha' + \beta' + \gamma' + \alpha'' + \beta'' + \gamma''$ 

## ALLOCREADIDÆ.

<i>Allocreadium isoporum</i> .....	$\alpha' + \beta' + \gamma' + \vartheta' + \alpha'' + \beta''$
<i>Acrolichanus petalosa</i> .....	$\alpha' + \beta' + \alpha'' + \beta'' + \gamma'' + \varphi''$

## FURCOCERCARIÆ.

<i>Cercaria of Schistosoma japonicum</i> .....	}	$\alpha + \beta$
<i>Cercaria douthitti</i>		
<i>Cercaria elephantis</i>		
<i>Cercaria furcicauda</i>	}	$\alpha + \beta + \gamma$
<i>Cercaria emarginatæ</i> .....		
<i>Cercaria douglasi</i>		
<i>Cercaria robusticauda</i>	}	$\alpha + \beta + \gamma + \vartheta$
<i>Cercaria quattuor-solenata</i> .....		
<i>Cercaria rhabdotæca</i> .....		$\alpha + \beta + \gamma + \vartheta + \epsilon$

## DESCRIPTION OF NEW SPECIES CITED IN THIS PAPER.

*Cercaria complexa* nov. spec. (Fig. 2.)

Systematic position: echinostome larva.

Parthenita: redia.

Host: *Planorbis trivolvis* Say.

Habitat and time of collection: drainage ditch, Urbana, Ill., 1918.

Flame-cell formula:  $\alpha + \beta^n = 3 + 12$  or 15.

Body 0.36 mm. long by 0.10 mm. wide; tail 0.36 mm. long by  $35\ \mu$  in diameter at base. Oral sucker  $35\ \mu$  in diameter, acetabulum  $50\ \mu$  in diameter. Entire ventral surface of body between pharynx and acetabulum sunken into elongate bowl-like sucking organ. Collar spines 38, disposed in two alternating rows.

Redia with conspicuous "feet," rhabdocœl gut, collar prominence and birthpore.

Prepharynx short; pharynx urn-shaped; esophagus long, capillary; furci distended, extending to posterior tip of body. Mucin glands six, with ducts tipped with piercing spines.

Excretory tubules with double flexure; 15 flame cells along the entire length of the tertiary portion.

*Cercaria trifurcata* nov. spec. (Fig. 5.)

Systematic position: stylet larva.

Parthenita: sporocyst.

Host: *Physa gyrina* Say.

Habitat and time of collection: drainage ditch, Urbana, Ill., 1918.

Flame-cell formula:  $\alpha' + \beta' + \alpha'' + \beta'' + \gamma'' = 3 + 3 + 3 + 3 + 3$  or 15.

Body 0.43 mm. long by 0.2 wide in region of acetabulum; tail 0.43 mm. long by  $50\ \mu$  in diameter at base, fluted laterally in distal half. Entire body covered with minute spines.

Sporocyst consisting of elongate compound branches.

Acetabulum  $60\ \mu$  in diameter; weak and ineffective; oral sucker  $76\ \mu$  in diameter, directed anteriad. Prepharynx provided with great mass of secretory glands; pharynx and esophagus present but inconspicuous; ceca broad sacculate pouches extending some distance behind the acetabulum; mucin glands several, in vitiform cluster, with granular contents, emptying through long ducts at sides of stylet.

Bladder small, crenate; main collecting tubule Y-form; anterior collecting tubule of each half of body with two triplet groups of flame cells and posterior collecting tubule with three triplet groups of flame cells.

*Cercaria candelabra* nov. spec. (Fig. 4.)

Systematic position: stylet larva.

Parthenita: sporocyst.

Host: *Planorbis trivolvis* Say.

Habitat and time of collection: drainage ditch, Urbana, Ill., 1918.

Flame-cell formula:  $\alpha' + \beta' + \gamma' + \alpha'' + \beta'' = 3 + 3 + 3 + 3 + 3$  or 15.

Body 0.25 mm. long by 0.09 mm. wide; tail two-thirds to three-fourths of body length. Integument heavy; body entirely covered with spines. Oral and ventral suckers  $44 \mu$  in diameter. Stylet in roof of oral sucker  $25 \mu$  long. Tail inserted into caudal pocket with a lateral pair of about ten heavy spines each.

Sporocyst simple, unbranched.

Prepharynx short; pharynx simple; glands crowding parenchyma emptying into pharynx; esophagus moderately long; ceca long, small, to subcaudal region of body. Mucin glands in vitiform clusters, antero-laterad to ceca, opening through long narrow ducts at sides of stylet.

Excretory bladder consisting of proximal and distal vesicles separated from one another by slightly muscular sphincter; collecting tubule emerging from each side of anterior vesicle with anterior tributaries from three triplet groups of flame cells and with posterior tributaries from two triad groups of flame cells.

*Cercaria furcicauda* nov. spec. (Fig. 6.)

Systematic position: furcocercous larva.

Parthenita: sporocyst.

Host: *Anculosa carinata* Brug.

Habitat and time of collection: Rome, Georgia, 1918.

Flame-cell formula:  $\alpha + \beta + \gamma = 2 + 2 + 2$  or 6.

Forked-tailed cercaria with body 0.26 mm. long and 0.12 mm. wide; tail trunk equally long; furci two-thirds length of tail trunk, extending at right angles to trunk. Anterior region of body covered with minute spines. Oral sucker  $48 \mu$  in diameter, directed anteriad; acetabulum  $40 \mu$  in diameter, at beginning of posterior third of body. Eye-spots wanting.



Sporocyst simple, sausage-shaped sac.

Prepharynx and pharynx simple; esophagus moderately long; ceca typically furcate. Mucin glands two pairs, opening through long ducts at sides of oral atrium.

Excretory bladder small; collecting tubules swollen at base; three pairs of flame cells with capillaries opening into each collecting tubule, one flame cell of posterior couplet running back into tail.

Mass of germ cells just anterior to bladder.

*Cercaria robusticauda* nov. spec. (Fig. 7.)

Systematic position: furcocercous larva.

Parthenita: sporocyst.

Host: *Physa gyrina* Say.

Habitat and time of collection: drainage ditch, Urbana, Ill., 1918.

Flame-cell formula:  $\alpha + \beta + \gamma + \vartheta = 1 + 2 + 2 + 2$  or 7.

Minute forked-tailed cercaria with body  $75\ \mu$  in length by  $25\ \mu$  in width, tail trunk equally long, but with short, stubby furci. Oral sucker  $12\ \mu$  in diameter, directed forward; ventral sucker equal in diameter, somewhat back of middle of body, with two concentric rings of spines. Blunt spines covering anterior third of body. Eye-spots wanting. Morphological pharynx degenerate, with glandular instead of muscular cells; esophagus leading into furci which meander to posterior margin of acetabulum. Mucin glands about six on each side, homogeneous in character, opening through single ducts at each side of the oral aperture.

Excretory bladder bicornuate, with single collecting tubule running into cornu on each side. Flame cells based on four-unit plan, with a single cell in the anteriormost unit and a pair in each of the succeeding three.

Germ cells, consisting of a loose aggregate, in front of the bladder.

*Cercaria quattuor-solenata* nov. spec. (Fig. 8.)

Systematic position: furcocercous larva.

Parthenita: sporocyst.

Host: *Anculosa carinata* Brug.

Habitat and time of collection: Rome, Georgia, 1918.

Flame-cell formula:  $\alpha + \beta + \gamma + \vartheta = 2 + 2 + 2 + 2$  or 8.

Forked-tailed cercaria with body 0.4 mm. long by 0.19 mm. wide, with tail trunk equally long and with furci about 0.26 mm. long, terminating in very short spinose porcesses. Eye-spots wanting.

Acetabulum  $20\ \mu$  in diameter, in posterior fourth of body; oral sucker  $70\ \mu$  in diameter, opening anteriad. Pharynx  $30\ \mu$  in trans-section; esophagus of narrow bore, opening into thin glandular-walled ceca which run caudad as far as the bladder. Mucin glands wanting.

Sporocyst simple, sausage-shaped sac.

Excretory bladder oval, depressed; collecting tubules four to each side, arising simultaneously from the bladder. Flame cells in four paired groups, the posterior pair being in the tail.

Large mass of germ cells midway between acetabulum and bladder.

*Cercaria rhabdocaeca* nov. spec. (Fig. 9.)

Systematic position: furcocercous larva.

Parthenita: sporocyst.

Host: *Planorbis trivolvis* Say.

Habitat and time of collection: slough, Urbana, Ill., 1918.

Flame-cell formula:  $\alpha + \beta + \gamma + \vartheta + \epsilon = 2 + 2 + 2 + 2 + 2$  or 10.

Forked-tailed cercaria with body 0.14 mm. long by 0.06 mm. wide, with tail trunk practically twice as long, and with furci 0.2 mm. in length. Anterior part of body provided with thick blunt spines. Acetabulum wanting; oral sucker pyriform, with larger end directed inward. Eye-spots wanting.

Sporocyst sacculate, with muscular pocket (not a digestive tract) and birthpore at anterior end.

Prepharynx present; pharynx only slightly muscular; esophagus short and inconspicuous; cecum single median. Mucin glands three to each side of the body, opening through individual ducts at sides of oral aperture. Duct pores capped with hollow piercing spines.

Excretory bladder simple, with collecting tubule emerging

from each side. Flame cells consisting of five paired groups on each side of body.

A few large germ-gland cells located ventral to bladder.

#### SUMMARY.

1. The number and distribution of groups of flame cells is the fundamental basis of structure of the excretory system of the distomes. Number of flame cells in each group and total number of flame cells are of secondary significance.

2. The group of flame cells is typical of all members of a family or at least of a subfamily.

3. The basic flame-cell group of each family or subfamily may be expressed as a general formula. Substitution in this general formula for the exact number of flame cells in each group shows variations within individual units, which, in each case, are multiples of the common denominator on which the general formula is based.

4. Seven new species of distome cercariæ are described, which are of special importance in affording evidence of the orderliness of the excretory system of the Digenea.

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